Progress on Microcalorimeters

Constellation-X Facility Science Team Meeting

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Introduction	Richard Kelley (GSFC)
GSFC/NIST/SAO Progress	Gene Hilton (NIST) Caroline Stahle(GSFC) Eric Silver (SAO)
Lawrence Livermore Progress	Mark Cunningham (LLNL)
Stanford University Progress	Tali Figueroa (Stanford/GSFC)
Summary and Issues	Richard Kelley

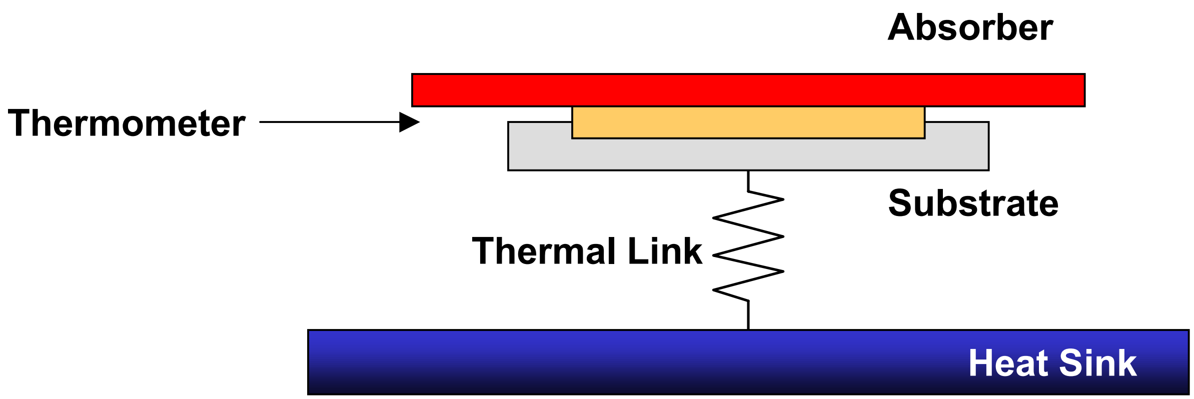
Development Priority

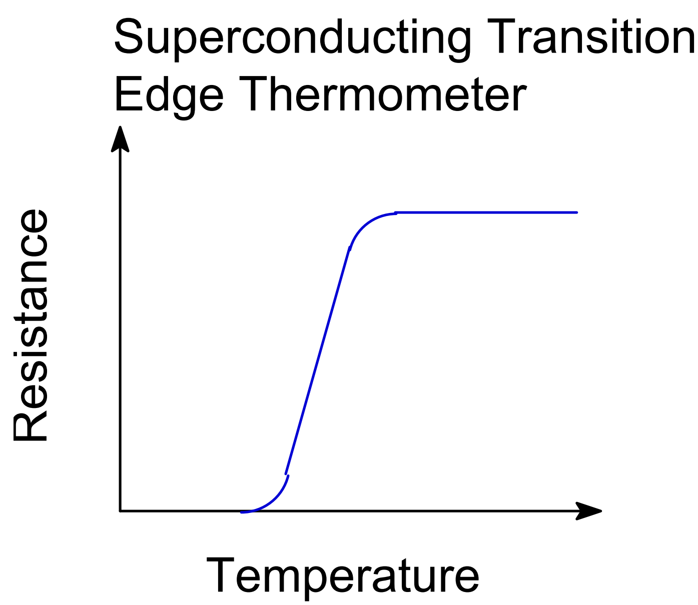
1. Energy resolution of 2 eV.

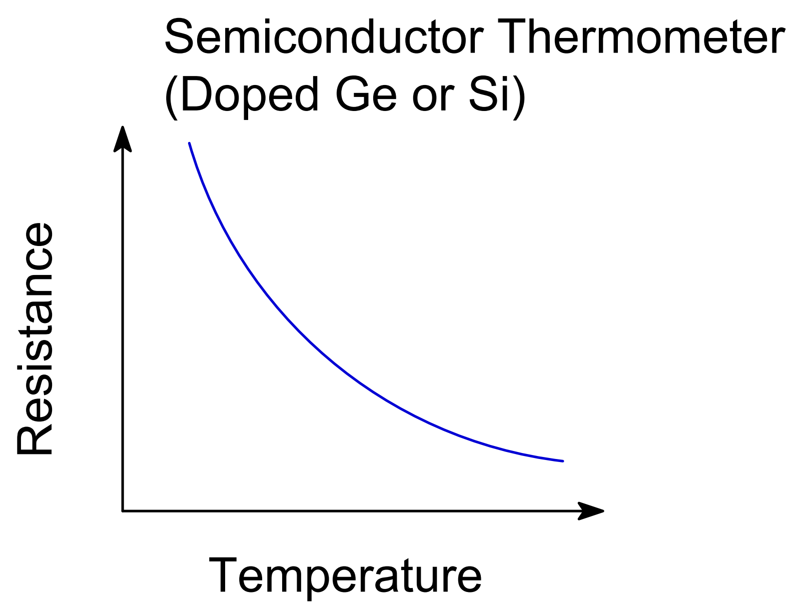
2. Maximum field of view while maintaining imaging capability. Current baseline is 32×32 array of 5” pixels, 2.7 arcmin FOV to accommodate a 15” HPD mirror.

3. Maintain reasonably low deadtime for 2 eV resolution at 1000 cps in peak pixel for point source.

Working on two general approaches:







Summary and Issues

- Excellent progress has been made on energy resolution and array components:

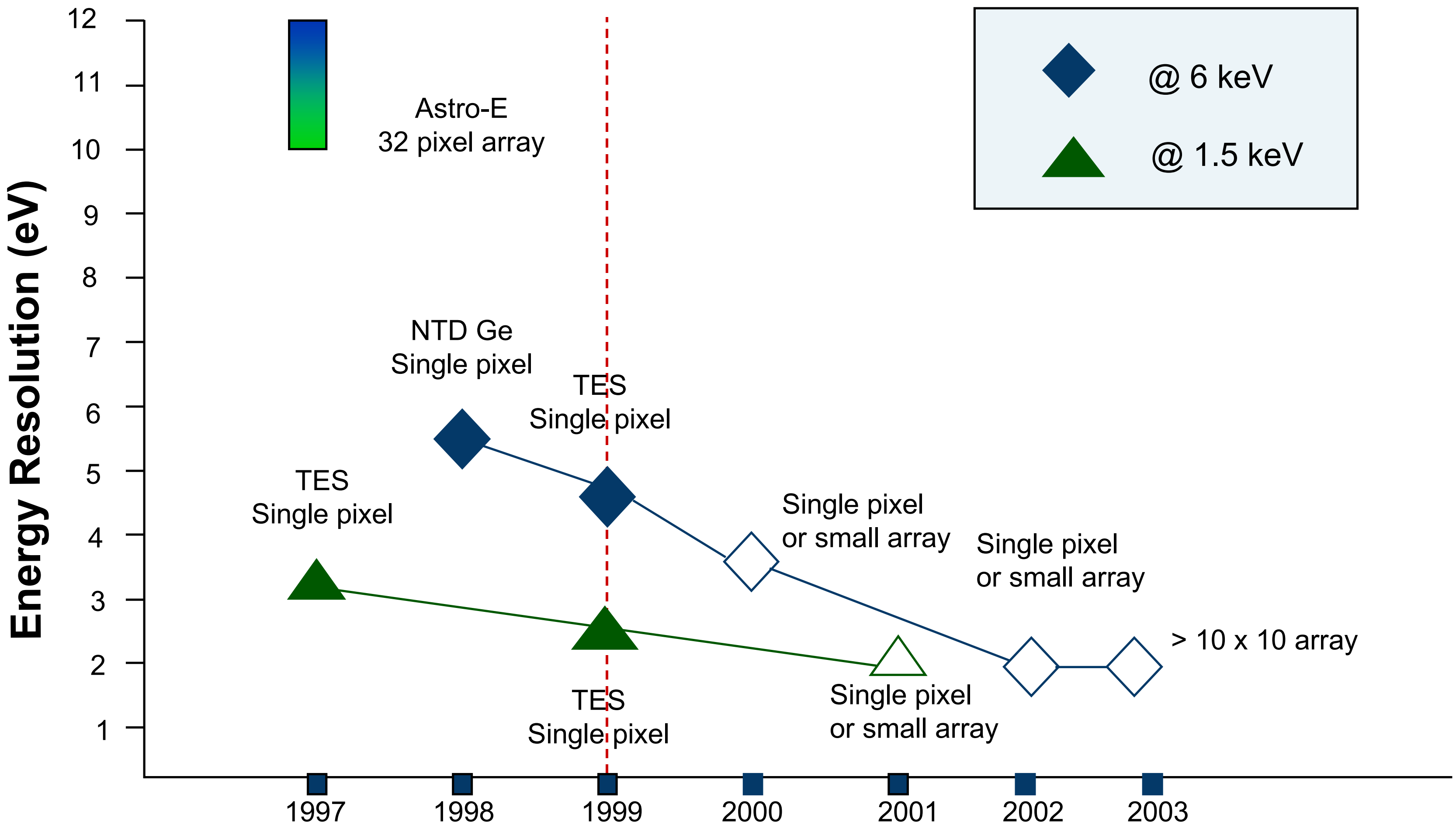
  2 eV at 1.5 keV and 4.5 eV at 6 keV

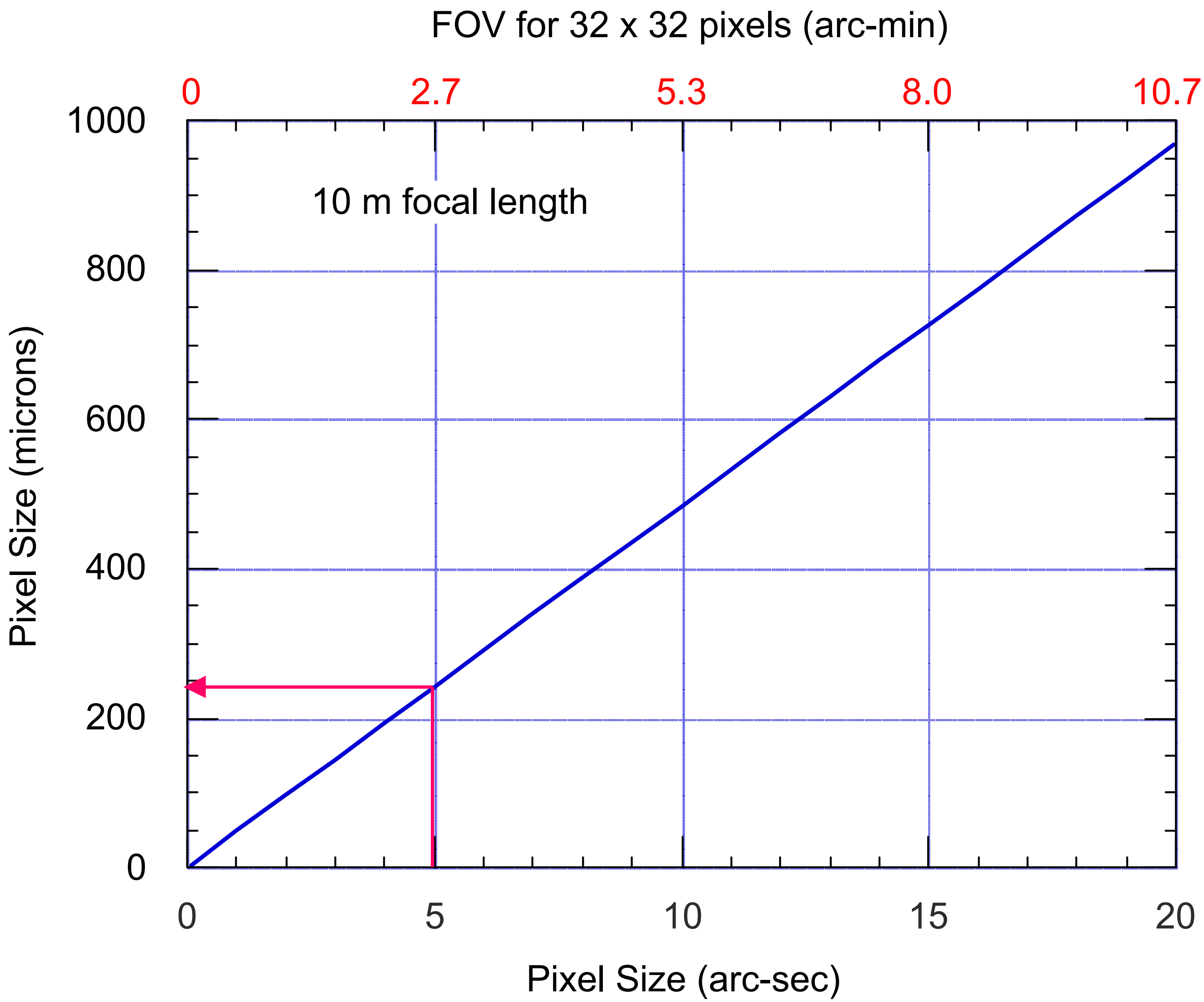
Concern for Project:

- Still working with single pixel, proof of concept devices.

- We need to put a lot of effort into developing arrays and a readout scheme extendable to large numbers of pixels (e.g., 32×32).

X-ray Calorimeters Metrics




FOV for 32 x 32 pixels (arc-min)
0
2.7
5.3
8.0
10.7
1000
800
600
400
200
0
10 m focal length
Pixel Size (microns)
0
5
10
15
20
Pixel Size (arc-sec)

Some Issues with Going to Smaller Pixels

Potentially makes the fabrication more difficult (250 μm is already a challenge)

- Getting discreet signals out requires smaller traces.

- Gaps between pixels will now be a larger fraction of pixel area, resulting in lower filling factor. Assuming 100 μm pixels: 10 μm gap gives 83% array filling factor
  6 μm gap gives 89% array filling factor

Will likely have an impact on detector performance

- Smaller devices will have higher power densities, which leads to e^- - phonon decoupling and current noise. These degrade the energy resolution.

- There will be a maximum allowable value for the thermal conductance, G. Higher G requires higher bias power density to attain optimal bias point. Smaller structures will have higher G if the conductance is diffusive (scales as $\mathcal{A}/\ell$).

Radiation Effects on Microcalorimeters

Doped semiconductors	JFETs
Superconducting films	SQUIDs

Don’t *expect* high sensitivity to radiation damage:

- Generally flowing relatively high currents compared with transferring very small amounts of charge.
- Semiconductor thermometers are heavily doped.
- Using polycrystalline materials.
- JFETs and SQUIDs have been successfully tested for other programs.
- *Limited* tests with ion-implanted Si and HgTe absorbers in Astro-E/XRS program did not reveal any problems or issues.

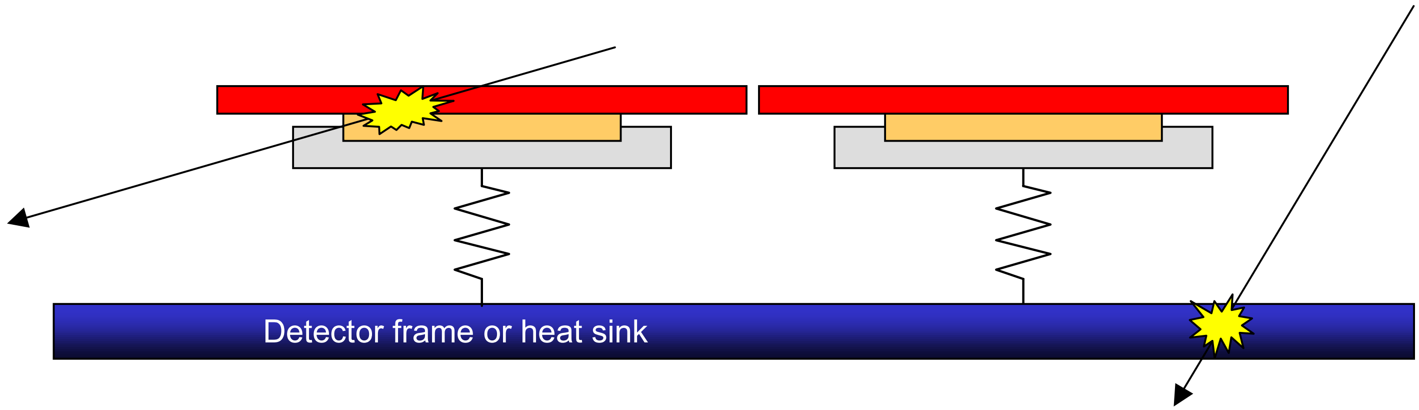
However…
- Very limited spaceflight history (only 10 min on two sounding rocket flights)
- We will not have any experience with microcalorimeters at L2; just *Astro-E* in LEO

We will have to test OUR mission-specific technology.

Thermal Effects of Particle Radiation

Thermal effects of cosmic rays are potentially a serious issue for microcalorimeters. Cosmic-ray particles that only pass through a pixel simply heat up that pixel (and possibly neighboring pixels), and can be rejected on the basis of pulse shape or an anticoincidence detector. However, a cosmic-ray particle that deposits a large fraction of it's energy in the frame of the array may cause it to heat up significantly, thus changing the response of *all* pixels until the frame temperature returns to equilibrium.

In low earth orbit (outside of SAA), most primary cosmic-rays are very energetic and leave only a certain minimum ionizing energy. Without geomagnetic shielding, e.g., at L2, the full spectrum of cosmic-rays will pass through the detector system. At lower energies, the energy loss per unit length increases significantly, and a particle can deposit a large fraction of it's initial energy, or even be completely stopped in the detector frame.



Minimizing this effect will require engineering the detector frame and heat sink to have high heat capacity, high thermal conductance to the ADR, and a high bandwidth thermometer to allow gain corrections.

Also need to investigate cosmic ray heating of ADR salt pills.